(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 December 2003 (18.12.2003)

PCT

(10) International Publication Number
WO 03/104673 A1

(51) International Patent Classification[7]: F16D 47/04, 27/105, 41/20

(21) International Application Number: PCT/CA03/00852

(22) International Filing Date: 10 June 2003 (10.06.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/386,755 10 June 2002 (10.06.2002) US

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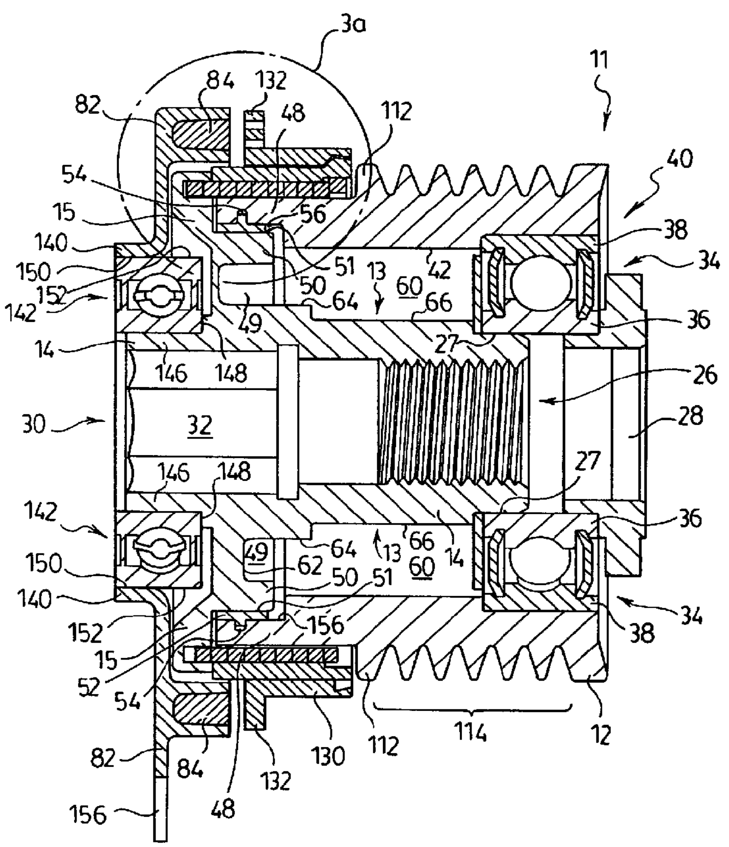
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),

[Continued on next page]

(54) Title: OVERRUNNING ENABLED AUTOMOTIVE STARTER/GENERATOR



(57) Abstract: An overrunning-enabled alternator/generator assembly includes a start mode clutch assembly (80) which selectively interlocks the pulley (112) to the hub (14) such that they rotate as a unit, thereby enabling the overrunning-enabled alternator/generator to be used as a starter to start the automotive engine to'which the alternator/generator is mounted as part of an accessory drive system. Conversely, a starter-type alternator/generator is provided with overrunning capabilities, whereby the starter/generator hub is able to overrun the starter/generator pulley.

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European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

OVERRUNNING ENABLED AUTOMOTIVE STARTER/GENERATOR

Field of the Invention

[0001] In general, the invention relates to an automotive starter/generator or other apparatus having rotary driving and driven components. More particularly, the invention relates to a starter/generator that is configured to permit overrunning of the starter/generator armature relative to the automotive belt drive system of which it is a part when the belt drive system slows relative to the starter/generator armature.

Background of the Invention

[0002] As illustrated in FIGURE 1, serpentine accessory drive systems for automotive vehicles are commonly used to transfer power, via associated pulleys, from an internal combustion engine crankshaft to accessory components typically including an alternator (generator), water pump (not shown), oil pump (for power steering), and/or an air conditioning compressor. These components are usually mounted in fixed positions and require an automatic belt tensioner to provide constant belt tension and to take up slack in the belt.

[0003] Internal combustion engines generate rotary power at the crankshaft only when a combustion event occurs. Thus, the serpentine drive system is, in effect, a pulsed system in which the closer together (in time) the combustion events is, the smoother the rotational consistency of the engine will be. For each combustion stroke, the crankshaft will accelerate then decelerate until the next combustion stroke. In general, the slower the rotation of the engine and the lower the number of cylinders (combustion events per revolution of the crankshaft), the greater the magnitude of the pulsing effect will be. Fuel burn characteristics also have a substantial influence on the effect; for example, the instantaneous acceleration of the crankshaft on a diesel engine is much greater than on a similar, gasoline-fueled engine due to the different nature of the combustion process itself.

[0004] As the crankshaft pulses are transferred to the drive belt, the drive belt velocity will fluctuate. Thus, engine velocity fluctuations are transferred to all of the drive system components, and the velocity fluctuation causes dynamic belt tension fluctuation. Even without taking dynamic loading of the accessory components and consequent tension effects into consideration, it is obvious that the driven inertias will

generate dynamic tensions as the belt continuously attempts to accelerate and decelerate these components.

[0005] In cases where the engine is relatively small (e.g., has four or five cylinders), and/or when the engine is operating in the lowest speed ranges (e.g., is idling), dynamic tension fluctuation will be at its greatest. Dynamic tension fluctuation magnitude can also increase due to technological system differences that lower the engine rotating inertia (e.g., dual-mass fly wheel) or that increase the instantaneous engine acceleration (e.g., using diesel fuel, higher compression ratios, etc.). Operating conditions such as "lugging" (where the engine is running below its ideal minimum speed (idle) at high power levels that attempt to increase the speed back to idle) also can have a significant effect on dynamic belt tension fluctuation.

[0006] Under such circumstances, dynamic belt loading can be so severe that the belt tensioner cannot accommodate all the dynamic fluctuations. As a result, the belt may squeal, slip, and/or vibrate and/or cause the tensioner and/or accessory components to vibrate. Ultimately, durability of the entire system may be compromised.

[0007] Because the rotational inertia of the alternator or generator armature is one of the highest rotational inertias in the system, a number of approaches have been developed to reduce such system degradation caused by dynamic belt tension fluctuation as the crankshaft accelerates and decelerates while the alternator or generator armature, with its generally high rotational inertia, tends to rotate at a far more constant or uniform rotational velocity. In particular, commonly assigned U.S. Patent No. 5,156,573, the disclosure of which is incorporated by reference, discloses a serpentine drive system for an automotive vehicle. The preferred embodiment of the mechanism shown in that patent uses a generally helical torsion spring (a resilient member) that is connected in series with a one-way clutch mechanism (wrap spring clutch), both of which are operatively located between the alternator driving pulley and the alternator armature. The arrangement transmits rotational torque from the alternator pulley through an alternator hub to drive the alternator armature in the same direction as the pulley, while at the same time permitting instantaneous, resilient, relative rotational movement in opposite directions between the pulley and the hub during driven rotation of the pulley; and decouples the alternator pulley from the hub

so that the hub structure (and hence the alternator armature) can rotate faster than the alternator pulley when the engine output shaft decelerates to such an extent that the torque generated between the alternator pulley and the hub structure exceeds a predetermined negative level.

[0008] Alternatively, commonly assigned U.S. Patent No. 6,083,130, the disclosure of which is also incorporated by reference, discloses an arrangement in which a resilient spring and a separately formed and provided one-way clutch mechanism are connected in series, and the combined spring/one-way clutch mechanism assembly couples the alternator pulley with the alternator hub structure. The resilient spring transmits rotational torque generated by the serpentine belt to the alternator pulley (and hence to the alternator hub structure and armature) to drive the alternator shaft in the same direction as the alternator pulley while permitting instantaneous, resilient, relative rotational movement in opposite directions between the pulley and the alternator hub during driven rotation of the pulley. The one-way clutch portion, which preferably is configured to be "self-energizing," is configured to engage the resilient spring to the alternator pulley when the pulley is being positively driven by the belt; on the other hand, the one-way clutch is constructed and arranged to allow the alternator hub structure (and hence the alternator armature) to rotate faster than the rotational speed of the alternator pulley when the engine output shaft decelerates to such an extent that the torque generated between the alternator pulley and the alternator hub structure exceeds a predetermined (negative) level. In some embodiments disclosed in that patent, the resilient member is a torsional spring made from spring steel; in other embodiments, the resilient member is made from "spokes" or "struts" or rubber "inserts" that are arranged between the alternator hub structure and a bearing plate, and the one-way clutch mechanism is arranged between the bearing plate and the alternator pulley.

[0009] In addition to advances being made in decoupling the alternator pulley and shaft, an emerging trend in the automotive industry is to use "combination" alternator/starter units in place of strictly power-generating alternators or generators. Such combination units are used both to generate electricity for the vehicle's electrical system while the engine is running and as a starter motor for the engine. When the engine is running, the crankshaft transmits rotational power to the alternator pulley

(via the accessory drive belt), which rotates the alternator armature to generate electrical power. When using the alternator as a starter motor, in contrast, the "roles" of the crankshaft and the alternator pulley are reversed. In particular, when using the alternator as a starter motor, electricity is supplied to the alternator/starter to cause the alternator armature to rotate, thereby rotating the alternator pulley and hence driving the engine crankshaft via the belt and the crankshaft pulley to start the engine.

[0010] Furthermore, during engine startup, the input and output "roles" or functions of the alternator pulley and alternator hub structure are reversed as compared to the ordinary input and output relation that exists during ordinary (e.g., driving) operation of the engine (in which ordinary operation the engine/crankshaft drives the alternator (as opposed to vice-versa)). The relative nature and direction of the torque between the alternator/generator hub and pulley will, accordingly, also be reversed when the alternator is being used to start the engine as compared to the ordinary situation in which the engine (the crankshaft) drives the alternator.

[0011] Such reversed relative torque is precisely the sort of "reversed" torsional relationship under which the clutch mechanism in each of the two above-referenced U.S. patents decouples the alternator pulley from the alternator hub structure, thereby allowing the alternator hub (and hence the alternator armature) to "overrun" the alternator pulley. Consequently, prior to the present invention, it has not been possible to provide starter/generator-type alternators with the overrunning protection afforded by a resilient coupling/decoupling mechanism like those disclosed in the two above-referenced U.S. patents or otherwise. Conversely stated, it has not been possible to use an overrunning-enabled alternator as a starter/generator.

1. Summary of the Invention

[0012] The present invention overcomes that limitation of the prior art, thereby facilitating overrunning capabilities in a starter/generator-type alternator. Conversely stated, an overrunning-enabled alternator can now be used as a starter/generator.

[0013] Thus, the invention features an overrunning-enabled starter/generator assembly which can be used to start an automotive engine to which the starter/generator assembly is to be mounted as part of the accessory drive system. The starter/generator assembly includes an alternator/generator body, which generates

electric power when being driven and which can be used as a rotary driving member when electric power is supplied to it.

[0014] The assembly has an overrunning-enabling hub/pulley assembly, connected to the alternator shaft, by means of which rotary power is provided to the alternator (e.g., from the crankshaft) and by means of which rotary power is provided from the alternator to driven means (e.g., the crankshaft) during engine start-up. The hub/pulley assembly includes a hub and a pulley which are interconnected in an overrunning-enabling manner such that during ordinary, driven operation, the pulley transfers rotary power to the hub, and hence to the alternator shaft, when rotary power is being applied to the pulley, and the hub is able to overrun the pulley when no rotary power is being applied to the pulley and the pulley slows relative to the hub or when insufficient rotary power is being applied to the pulley for the pulley to be able to drive the hub.

[0015] The hub/pulley assembly further includes a start mode or second clutch assembly arranged to selectively lock the pulley to the hub so that the hub and pulley can rotate as a single unit, without the hub overrunning the pulley, when it is desired to use the alternator to start the engine by driving the crankshaft – a mode of operation which otherwise would cause the hub to slip relative to the pulley as explained above.

[0016] More broadly speaking, the invention features a coupling assembly including a hub, a pulley that is mounted to and rotates on the hub, and a first or overrunning clutch operatively engaging the hub and the pulley. The overrunning clutch enables the pulley to drive the hub while allowing the hub to overrun and rotate relative to the pulley.

[0017] The coupling assembly includes a second clutch assembly operatively engaging the hub and the pulley, which second clutch assembly selectively interconnects the hub and pulley to enable the hub to drive the pulley without overrunning or slipping relative to the hub.

[0018] In preferred embodiments, the pulley and the hub are interconnected (to permit overrunning) by means including a torsion spring and by means further including a wrap spring clutch connected in series with the torsion spring. Other one-way clutch devices can also be employed, e.g., a roller clutch. The arrangement can be such that the hub is able to overrun the pulley as soon as the pulley slows relative

to the hub, or it can be such that the hub is able to overrun the pulley only after a predetermined, negative level of relative torque between the hub and the pulley is exceeded.

[0019] The start mode clutch assembly, which may be electromagnetically actuated, includes a wrap spring clutch that interlocks the pulley to the hub when the start mode clutch assembly is actuated. The wrap spring clutch is fixed to the hub and overlies a wrap spring-engaging clutch surface of the pulley. Preferably, the wrap spring clutch is configured, based on the direction of rotation of the pulley, such that the wrap spring clutch is self-energizing, whereby the volutes of the wrap spring clutch automatically constrict down into clutching engagement with the wrap spring-engaging clutch surface of the pulley when a portion of a volute of the wrap spring clutch is brought into contact with the wrap spring-engaging clutch surface.

[0020] The start mode clutch assembly further includes a wrap spring actuator ring which surrounds the wrap spring clutch and which initiates interlocking clutching operation of the wrap spring clutch. The wrap spring actuator ring is configured to press a portion of a volute (e.g., a free end of the wrap spring clutch) into engagement with the wrap spring-engaging surface when the start mode clutch assembly. In particular, a lever driver ring surrounds the wrap spring actuator ring and causes the wrap spring actuator ring to press the volute into engagement with said wrap spring-engaging surface when the start mode clutch assembly is actuated.

[0021] The wrap spring actuator ring has a flexural finger portion that flexes radially inwardly and that is disposed so as to press the volute into engagement with the wrap spring-engaging surface, and the lever driver ring slides axially relative to the wrap spring actuator ring. The flexural finger portion and the lever driver ring have opposing ramped surfaces which cooperate to cause the flexural finger portion to press the volute into engagement with the wrap spring-engaging surface as the lever driver ring slides axially relative to the wrap spring actuator ring.

[0022] According to one aspect of the invention, there is provided an alternator assembly having a shaft that is rotatably mounted within a housing. The alternator assembly is configured such that during a driven mode of operation in which the shaft is externally rotated, the alternator produces or outputs electrical power. During a driving mode of operation in which electrical power is supplied to

the alternator assembly, the shaft is caused to drivingly rotate producing a rotary output. A coupling assembly mounts on the alternator shaft for selectively transferring rotary power to and from the shaft. The coupling assembly has a hub that is mounted on the shaft. A pulley is rotatably mounted on the hub. A first clutch operatively engages the hub and the pulley, enabling the pulley to drive the hub while allowing the hub to overrun and rotate relative to the pulley. A second clutch assembly operatively engages the hub and pulley, selectively interlocking the hub and pulley enabling the hub to drive the pulley.

Brief Description of the Drawings

[0023] The invention will now be described in greater detail in connection with the drawings, in which:

[0024] FIGURE 1 is a schematic, lay-out depiction of a serpentine accessory drive system for automotive vehicles;

[0025] FIGURE 2 is a perspective view illustrating one embodiment of an overrunning-enabled starter/generator assembly according to the invention, with FIGURE 2a being a view, partially in section, taken along lines 2a-2a in FIGURE 2;

[0026] FIGURE 3 is a cross sectional view of the hub/pulley assembly of the overrunning-enabled starter/generator assembly according to the invention shown in FIGURE 1, with FIGURE 3a being an enlarged, detail view of the circled portion 3a in FIGURE 3;

[0027] FIGURES 4, 4a, 5, and 6 illustrate the components of an electromagnetically actuated start mode clutch assembly that is part of the overrunning-enabled starter/generator assembly according to the invention shown in FIGURE 1, with FIGURE 4 being a perspective view of the start mode clutch assembly, FIGURE 4a being an enlarged, detail view of the circled portion 4a in FIGURE 4, FIGURE 5 being a plan view of the start mode clutch assembly, and FIGURE 6 being a cross sectional view of the start mode clutch assembly taken along lines 6-6 in FIGURE 5; and

[0028] FIGURE 7 is a cross sectional view of a hub/pulley assembly according to a second embodiment of the overrunning-enabled starter/generator assembly.

[0029] FIGURES 8 and 9 are cross sectional views a hub/pulley assembly according to a third embodiment of the overrunning-enabled starter/generator assembly.

Detailed Description of Embodiments of the Invention

[0030] Referring now more particularly to the drawings, there is shown in FIGURE 1 an automotive internal combustion engine, which includes an engine block and a crankshaft. Fixed to the crankshaft is a crankshaft pulley 11 forming a part of a serpentine belt system. The belt system includes an endless belt 13. The belt 13 is a poly-V belt. The belt 13 is trained about the drive pulley 11 and a plurality of further pulleys 15 and 17 each of which is fixed to respective shafts that are connected to operate various engine accessories. For example, pulley 15 drives a power steering device, pulley 17, an air conditioning system and other known accessories. Belt 13 is also provided with an idler 19 and a tensioner 21. Belt 13 is also trained about alternator assembly 10 of the present invention.

[0031] An overrunning-enabled starter/generator alternator assembly according to the invention is illustrated in FIGURES 2-6. As illustrated in FIGURES 2, 3, and 3A, an alternator assembly according to the invention, designated generally as reference numeral 10, includes a pulley 12, a hub 14, and an alternator body assembly 16. As is known in the art, the alternator body assembly 16 includes a stator with a multiplicity of conductors wound thereon and an alternator armature that rotates within the stator to generate electricity. The alternator is of the generator type, which is also generally known in the art. The alternator body assembly 16 further includes mounting brackets 18 by means of which the alternator assembly 10 is mounted to an automotive engine.

[0032] The armature shaft extends axially outwardly from the alternator body assembly 16, i.e., away from the alternator body assembly. (As used throughout this description, the term "axially inward" or "axially inner" refers to the direction toward or the side or end of a component that is closest to the alternator body assembly (the portion of the alternator housing the stator and the armature); the term "axially outward" or "axially outer," on the other hand, refers to the direction away from or the side or end of a component that is furthest from the alternator body assembly.) The distal or free end of the armature shaft is externally threaded, and the axially

inner end 26 of the hub 14 (i.e., that end that is located closer to the alternator body assembly 16) is correspondingly threaded so that the composite hub/pulley assembly 11 can be screwed onto the armature shaft. The axially outer end 30 of the hub 14 has a socket 32, e.g., a generally hexagonal or spline socket, by means of which a hex-wrench-type of tool can be used to tighten the hub/pulley assembly 11 onto the armature shaft. Steel spacer 28 (SAE 1117) fits over the alternator armature shaft with a locational or clearance fit and is disposed between the alternator front bearing (not shown) and the bearing 34 in order to maintain proper axial spacing of the hub/pulley assembly 11 relative to the alternator body assembly 16.

[0033] As further illustrated in FIGURE 3 in particular, the pulley 12 is mounted in concentric, radially outwardly spaced relationship to the central, core portion 13 of the hub 14. Axially inner bearing 34 is press fit over the outer peripheral surface 27 of the axially inner end 26 of the hub 14, with the inner race 36 of the axially inner bearing 34 being immovably secured to the outer peripheral surface 27 of the inner end 26 of the hub 14. Furthermore, the axially inner end 40 of the pulley 12 is press fit over the outer circumference of the axially inner bearing 34, with inner surface 42 of the pulley 12 frictionally and immovably engaging the outer surface of the outer race 38 of the axially inner bearing 34.

[0034] At the opposite, axially outer end 48 of the pulley 12, the pulley is supported in radially outwardly spaced relationship to circumferentially extending lip portion 50, which is located in the region where the core portion 13 of the hub 14 intersects or joins with radially enlarged flange portion 15 of the hub 14. In particular, a plastic bushing 52 fits within circumferentially extending annular groove 54 that is formed in the radially inner surface 56 of the axially outer end 48 of the pulley 12. The plastic bushing 52 circumferentially surrounds the lip portion 50, with the radially inner surface of the plastic bushing 52 contacting the radially outer surface 51 of the lip portion 50.

[0035] The plastic bushing 52 can be constructed and arranged such that it is relatively circumferentially fixed relative to the walls of the annular groove 54 and such that it is free to slide circumferentially relative to the radially outer surface 51 of the lip portion 50; conversely, the plastic bushing 52 can be constructed and arranged so as to slide circumferentially relative to the walls of the annular groove 54 while

being relatively fixed relative to the radially outer surface 51 of the lip portion 50. Alternatively, it can be constructed and arranged so as to be free to slide relative to both the walls of the annular groove 54 and the radially outer surface 51 of the lip portion 50 so long as, in total combination, the axially outer end 48 of the pulley 12 is free to rotate circumferentially relative to and concentrically with the lip portion 50 of the hub 14. Thus, to the extent the composite hub/pulley assembly 11 has been described so far, the pulley 12 is free to rotate circumferentially relative to and concentrically with the hub 14 by virtue of the arrangement of the axially inner bearing 34 and the plastic bushing 52 between the pulley 12 and the hub 14.

[0036] The pulley 12 is not, however, free to rotate relative to the hub 14 in completely free, unrestrained fashion. Rather, an overrunning-enabled decoupler assembly (not shown to improve the clarity of the FIGURES), e.g., of the sort disclosed in the above-referenced U.S. Patent No. 6,083,130, is operatively disposed within the annular space 60 that is radially bounded by the radially outer surfaces of the core portion 13 of the hub 14 and the radially inner surfaces of the pulley 12 and that is axially bounded by the axially inner bearing 34 and the circumferentially extending "pocket" 49 defined radially inwardly of the lip portion 50.

[0037] In particular, as in U.S. Patent No. 6,083,130, the axially outermost volute of a torsion spring is positioned within the circumferentially extending pocket 49, and the torsion spring extends axially inwardly toward (but not all the way to) the inner bearing 34. The axial depth of the circumferential pocket 49 decreases circumferentially around the hub 14 with the axial "progression" of the torsion spring volute around the circumference of the torsion spring to accommodate the helical configuration of the torsion spring; that depth-decreasing configuration of the circumferential pocket 49 permits the torsion spring to sit firmly and in well supported fashion against the bottom surface 62 of the circumferential pocket 49.

[0038] The end of the torsion spring butts up against the circumferential end wall (not visible) of the pocket 49 to drive the hub 14 in the driving direction. Conversely, because the torsion spring is axially compressed when the hub/pulley assembly 11 is assembled, it bears against the bottom of the pocket 49 with sufficient force for friction (as well as the slightly inclined nature of the bottom surface) to prevent the torsion spring form rotating in the opposite direction within the pocket 49.

[0039] As illustrated, the core portion 13 of the hub 14 has a radially stepped-down configuration such that the radially outer surface portion 66 of the core portion 13 of the hub 14 has a smaller diameter than the radially outer surface portion 64 of the core portion 13. This provides certain manufacturing advantages.

[0040] An overrunning-permitting wrap spring clutch, which is "oppositely" wound compared to the torsion spring, is connected in secure fashion to the axially inner end of the torsion spring, as per U.S. Patent No. 6,083,130. As explained more fully in that patent, when the engine is firing such that the belt is applying driving torque to the pulley 12, the inner surface 42 of the pulley 12 (which frictionally engages the free end of the wrap spring clutch) forces the free end of the wrap spring clutch in a circumferential direction which causes the volutes of the wrap spring clutch to tend to expand outwardly, thereby progressively energizing the entire wrap spring clutch by increasing the contact pressure of the wrap spring against the radially inner surface 42 of the pulley 12. Because the wrap spring clutch is joined in series with the torsion spring and the torsion spring is fixed at its axially outer end to the core portion 13 of the hub 14, the accessory drive belt is able to drive the alternator armature via the pulley 12, which acts torsionally and elastically through the wrap spring clutch and torsion spring to drive the hub 14.

[0041] On the other hand, when the engine crankshaft decelerates such that the linear velocity of the accessory drive belt decreases (and hence such that the rotational velocity of the pulley 12 decreases), the tendency is for the alternator armature, with its generally higher rotational moment of inertia, to rotate faster than the pulley 12, as explained above. In other words, the tendency is for the alternator armature to overrun the pulley 12.

[0042] As explained in U.S. Patent No. 6,083,130, such overrunning of the alternator armature (and hence of the alternator shaft) relative to the pulley 12 causes the free end of the wrap spring clutch to tend to slide circumferentially relative to the radially inner surface 42 of the pulley 12. The level of friction between the free end of the wrap spring clutch and the radially inner surface 42 of the pulley 12 is predetermined such that when the level of relative torque between the pulley 12 and the hub 14 exceeds a predetermined (negative) value, the free end of the wrap spring clutch will slip relative to the radially inner surface 42 of the pulley 12, thereby

allowing the hub 14 to rotate and "slip" relative to the pulley 12 and hence allowing the hub 14 (and thus the alternator armature) to overrun the pulley 12.

[0043] As explained above, that relative rotation and slippage between the hub 14 and the pulley 12 during overrunning would prevent an overrunning-enabling hub/pulley assembly as per the prior art from being used to enable alternator overrunning in a starter-type alternator/generator. The present invention solves that problem by incorporating an electromagnetically actuated start mode clutch assembly 80 into the hub/pulley assembly 11.

[0044] As illustrated in FIGURES 3-6, the start mode clutch assembly 80 includes a generally circular, electromagnet coil-supporting bracket plate 82. The bracket plate 82 houses and supports electromagnet coil 84, which might be embedded within resin or other housing material, within trough or pocket 86 extending circumferentially around the perimeter of the bracket plate 82. Additionally, the start mode clutch assembly 80 includes a start mode wrap spring 88; a wrap spring actuator ring 90; and a ferromagnetic, electromagnetically actuated lever driver ring 92.

[0045] As illustrated most clearly in FIGURE 3a, the start mode wrap spring 88 is formed from a number of closely spaced volutes of music wire or spring steel, preferably having a square cross-section. The radially inner surfaces of the volutes may or may not have a coating or layer of friction-enhancing material. The axially outer end 94 of the start mode wrap spring 88 is immovably press-fit into wrap spring-receiving trough or pocket 96, which extends circumferentially around the perimeter of the flange portion 15 of the hub 14. As further shown in FIGURE 3a, the inner diameter of the start mode wrap spring 88, which is constant along virtually its entire length, is slightly larger than the outer diameter of the axially outer end 48 of the pulley 12 (i.e., it is slightly larger than the outer diameter of the clutch surface 98 of the pulley). In particular, a gap 100 is formed between the inner surface of the start mode wrap spring 88 and the clutch surface 98, and that gap 100 is on the order of 0.25 millimeter. The start mode wrap spring 88 is flexurally stiff or rigid (i.e., it does not flex or bend in a direction perpendicular to its longitudinal axis) so that the press-fit engagement of the axially outer end of the start mode wrap spring within the

trough or pocket 96 is sufficient to keep the start mode wrap spring 88 properly spaced from and concentric with the axially outer end of the pulley 12.

[0046] As shown in FIGURES 3a, 4a, and 5, a tail end portion 102 of the axially innermost end of the start mode wrap spring 88, extending over an arc length of approximately 45°, is bent radially outwardly and is spaced slightly further from the wrap spring-engaging clutch surface 98 of the pulley 12 than the rest of the volutes of the start mode wrap spring 88. The tail end portion 102 is used to initiate constriction of the start mode wrap spring 88 into clutching engagement with the wrap spring-engaging clutch surface 98, which locks the pulley 12 to the hub 14 so that they rotate together as a unit as described in greater detail below.

[0047] As illustrated in FIGURES 3-6, wrap spring actuator ring 90 fits around start mode wrap spring 88 in closely surrounding (slight interference fit), concentric relationship with it. The wrap spring actuator ring 90 is made from relatively light, low-friction material such as nylon which prevents the wrap spring actuator ring 90 from binding on the outer surface of the start mode wrap spring 88. Additionally, the material from which the wrap spring actuator ring 90 is made prevents the lever driver ring 92 from "binding" on the exterior surface of the wrap spring actuator ring 90. Furthermore, the material from which the wrap spring actuator ring 90 is made permits flexural "finger" portion 104 to flex radially inwardly upon actuation of the start mode clutch assembly 80, as described in greater detail below.

[0048] The wrap spring actuator ring 90 has a slight amount of room to slide axially. At its axial outermost end 106, the wrap spring actuator ring 90 abuts surface 108 of the flange portion 15 of the hub 14. At its opposite, axially inner end 110, the wrap spring actuator ring 90 is restrained from shifting axially inwardly by the tail end portion 102 of the start mode wrap spring 88 and/or by axially outer groove stop 112 (which defines the axially outermost extent of the belt grooves 114 on the exterior surface of the pulley 12).

[0049] As shown most clearly in FIGURES 3 and 6, the wrap spring actuator ring 90 is generally uniformly cylindrical. At its axially inner end, however, the wall thickness of the wrap spring actuator ring 90 decreases slightly, as indicated by the radially outward "jog" 114 in the inner diameter of the wrap spring actuator ring.

That slight reduction in wall thickness helps to facilitate flexing of the finger portion 104.

[0050] As best illustrated in FIGURES 4a and 5, rim portion 116 of the wrap spring actuator ring 90 (which rim portion 116 is the portion of the wrap spring actuator ring 90 of reduced wall thickness) has two notches 118a and 118b formed in it. The arcuate extent of the rim portion 116 located between the two notches 118a and 118b forms the finger portion 104. As shown most clearly in FIGURES 3a and 6, the finger portion 104 protrudes or bulges radially outwardly to a slight degree. That radially outwardly protruding or bulging portion has a slanted lever surface 120 (the function of which is explained below) and an obtusely oriented, slanted, lever driver ring-retaining surface 122 (the function of which will also be described below).

[0051] As shown in FIGURES 4a and 5, a radially outwardly deepening (with progression in the circumferential direction) notch or pocket 124 is formed in the radially inner surface of the finger portion 104, which notch or pocket 124 accommodates the tail end portion 102 of the start mode wrap spring 88. As noted above, the tail end portion 102 of the start mode wrap spring 88 is used to initiate constricting, clutching engagement of the start mode wrap spring 88 with the wrap spring-engaging clutch surface 98 of the pulley 12, and finger portion 104 is used to press that tail end portion 102 into constriction-initiating engagement with the wrap spring-engaging clutch surface 98 (as will be described in greater detail below). Therefore, it is important for the finger portion 104 of the wrap spring actuator ring 90 to remain circumferentially aligned with the tail end portion 102 of the start mode wrap spring 88. The configuration of the start mode wrap spring 88 and the finger portion 104, with the tail end portion 102 of the start mode wrap spring 88 angling radially outwardly and fitting within the notch or pocket 124, keeps the start mode wrap spring 88 and the wrap spring actuator ring 90 properly circumferentially aligned.

[0052] Lever driver ring 92, which is made from ferromagnetic material such as steel, surrounds the wrap spring actuator ring 90. The protruding or bulging portion of the finger portion 104 of the actuator ring 90 fits within the finger portion-receiving indentation 126 extending circumferentially around the radially inner surface 128 of the cylindrical body portion 130 of the lever driver ring 92, at the

axially inner end thereof. Because the finger portion-receiving indentation 126 extends circumferentially around the entirety of the radially inner surface 128 of the lever driver ring 92, there is no need to provide for any circumferential alignment between the lever driver ring 92 and the wrap spring actuator ring 90, as is the case between the wrap spring actuator ring 90 and the start mode wrap spring 88. The lever driver ring 92 is sized such that the cylindrical body portion 130 of it fits over the radially outer surface of the wrap spring actuator ring 90 in generally closely conforming relationship. Therefore, although the two components are illustrated with a slight gap between them for clarity, the fit between them is a close running fit such that there is little or no "play" and so that the lever driver ring 92 does not vibrate or "chatter" against the wrap spring actuator ring 90 while the alternator pulley assembly 11 is spinning.

[0053] The lever driver ring 92 has a circumferential flange portion 132 that extends radially outwardly from the cylindrical body portion 130 and that is located at the axially outer end of the lever driver ring 92. As shown most clearly in FIGURE 5, the circumferential flange portion 132 has a radially inner series of circumferentially oriented arcuate slots 134a and a radially outer series of circumferentially oriented arcuate slots 134b. The slot configuration is a double flux design that increases the level of magnetic force generated when current flows through the electromagnet coil 84.

[0054] As noted above, the electromagnetic coil 84 is carried within coil-receiving trough or pocket 86 which extends circumferentially around the perimeter of the coil-supporting bracket plate 82. The coil-supporting bracket plate 82 is generally circular and has a circular, axially outwardly extending lip 140. Bearing 142 is press-fit onto the axially outer end 30 of the hub 14, with the inner race 144 of the bearing 142 being press-fit over reduced-diameter surface portion 146 of the axially outer end 30 of the hub and abutting annular shoulder surface 148 (which limits the extent to which the bracket plate-supporting bearing 142 can be pressed onto the axially outer end 30 of the hub). The coil-supporting bracket plate 82, in turn, is press-fit onto the bearing 142, with the radially inner surface 150 of the lip 140 making an interference fit with the outer surface 152 of the outer race of the

bearing 142. With this configuration, the hub 14 is positioned concentrically with and is able to rotate relative to the coil-supporting bracket plate 82.

[0055] As shown most clearly in FIGURE 2, a tab 156 extends from the edge of the coil-supporting bracket plate 82. The tab 156 has a generally U-shaped notch 158, and a pin (not shown) passes through the notch 158 and is secured to a stationary portion of the alternator body assembly 16. In this manner, the coil-supporting bracket plate 82 is prevented from spinning or rotating while the hub/pulley assembly 11 is spinning or rotating, since the bearing 142 permits such relative rotation between the hub 14 and the coil-supporting bracket plate 82.

[0056] Additionally, as shown in FIGURES 2 and 2a, a power lead socket 157 is also attached to the edge of the coil-supporting bracket plate 82. The power lead socket 157 has a pair of male electrical contact pins 159 located in it which mate with a corresponding pair of female electrical contact sockets (not shown) in a power supply plug (not shown). Such configuration permits rapid assembly and power connection to be made.

[0057] The overrunning-enabling starter/generator pulley assembly of the invention operates as follows. When the engine is running, the electromagnetic start mode clutch assembly 80 is non-activated, and the various components are spaced relative to each other generally as illustrated. As explained above, the decoupler assembly transmits rotary power (provided by the engine crankshaft) from the pulley 12 to the hub 14 when the engine is running and the crankshaft is driving the system (i.e., during combustion events), enabling the alternator assembly 10 to output electrical power. The decoupler assembly allows the hub 14 to "slip" relative to the pulley 120 during periods in which the hub 14 overruns the pulley 12 (e.g., during non-combustion time periods), preferably after a predetermined (negative) level of torque between the hub 14 and the pulley 12 has been exceeded. As further explained above, the torsion spring component of the decoupler assembly permits instantaneous, resilient, relative rotational movement in opposite directions between the hub 14 and the pulley 12 during driven rotation of the pulley 12.

[0058] During engine start-up, on the other hand, when the alternator assembly 10 is being used to start the engine, the electromagnetic start mode clutch assembly 80 is actuated. In particular, DC current is supplied to the electromagnet

coil 84 to generate a magnetic field, which attracts the lever driver ring 92 with a force on the order of one pound or less. That attraction forces the lever driver ring 92 to shift axially toward the electromagnet coil 84 by sliding over the radially outer surface of the wrap spring actuator ring 90 (with the amount by which the lever driver ring 92 shifts being a function of manufacturing tolerances). Because the axially outer end 106 of the wrap spring actuator ring 90 abuts end surface 108 of the flange portion 15 of the hub 14, the wrap spring actuator ring 90 is prevented from shifting axially with the lever driver ring 92. Therefore, as the lever driver ring 92 shifts axially toward the electromagnet coil 84, slanted lever driver surface 127 of the finger portion-receiving indentation 126 bears against the slanted lever surface 120 of the finger portion 104. Because the engaging surfaces are slanted or ramped relative to each other, the finger portion 104 is forced to flex radially inwardly as the lever driver ring 92 shifts axially toward the electromagnet coil 84. As the finger portion 104 is pressed radially inwardly, it presses the tail end portion 102 of the start mode wrap spring 88 into contact with the wrap spring-engaging clutch surface 98 of the pulley 12.

[0059] As electric current is supplied to the alternator armature and causes the hub 14 to rotate (upper portions thereof rotating "out of the page" and lower portions thereof rotating "into the page" as shown in FIGURE 3), the tail end portion 102 of the start mode wrap spring 88, which is held in contact against the clutch surface 98 of the pulley 12 by the finger portion 104, is dragged or pulled in the direction of rotation of the hub 14. As the tail end portion 102 of the start mode wrap spring 88 is pulled in that direction ("out of the page" as shown in FIGURE 3a), the volutes of the start mode wrap spring 88 constrict down into secure, clutching engagement with the wrap spring-engaging clutch surface 98 of the pulley 12. Accordingly, because the start mode wrap spring 88 is securely fixed to the hub 14 (by virtue of the press-fit engagement in wrap spring-receiving trough or pocket 96), the pulley 12 and the hub 14 will be locked together and will rotate as a single unit. In other words, the hub 14 will be prevented from slipping relative to the pulley 12 so that the alternator assembly will be able to drive the engine crankshaft (via the accessory belt) to start the engine.

[0060] It will be appreciated that because the tail end portion 102 of the start mode wrap spring 88 extends over a relatively small arcuate length (approximately 45°, as noted above), the amount of force required to press the tail end portion 102 into contact with the clutch surface 98 of the pulley 12 is relatively small. Moreover, it will be appreciated that the relatively high level of friction between the inner surface of the tail end portion 102 of the start mode wrap spring 88 and the clutch surface 98 of the pulley 12 quickly causes the entire start mode wrap spring 88 to constrict down into secure engagement with the clutch surface 98 of the pulley 12. Thus, the level of (magnetic) force required to be generated to initiate and maintain firmly clutched engagement between the pulley 12 and the hub 14 is relatively small, so clutching performance of the start mode clutch assembly is exceptionally efficient.

[0061] Once the engine has been started, the electromagnet coil 84 is de-energized, and the lever driver ring 92 shifts back toward the right (as shown in FIGURES 3 and 3a). The radial resiliency of the tail end portion 102 of the start mode wrap spring 88 and the radial resiliency of the finger portion 104 of the actuator ring 90 will force the slanted lever surface 120 of the finger portion 104 into contact with the lever driver surface 127 of the lever driver ring 92, and the force of the that angled, "camming" contact should suffice to cause the lever driver ring 92 to shift back to its non-activated position. Alternatively, to facilitate return of the lever driver ring 92 to its non-activated position, a return spring (not shown) could be arranged to bias the lever driver ring 92 toward its non-activated position.

[0062] Thus, with the configuration described above, an overrunning-enabled alternator can be used as a starter/generator, which has not been possible previously.

[0063] Referring to Figure 7, a second embodiment of the overrunning-enabled starter/generator is shown, wherein the pulley/hub apparatus is a one-way clutch (e.g., a roller clutch) instead of a torsion spring connected in series with a wrap spring. All components are generally identical to those illustrated and described above, with the exception being that the decoupling assembly 200 is a one-way roller bearing assembly, as is known in the art, and other components being modified in light of that difference as compared to the embodiment described above. (For example, there is no pocket in the flange portion 15' of the hub 14' to receive a torsion spring, as in the case of the embodiment described above.) Whereas the

overrunning-enabled hub/pulley assembly described above permits instantaneous, resilient, torsional rotation between the pulley 12 and the hub 14, and the hub 14 does not "slip" relative to the pulley 12 until after a predetermined (negative) level of relative torque has been exceeded when the alternator armature overruns the pulley, an alternator hub/pulley assembly using a one-way roller clutch to operatively interconnect the pulley and the hub will not permit such instantaneous, resilient, torsional rotation between the pulley and the hub when the pulley is driving the hub. Additionally, when the alternator armature (and hence the hub) begins to overrun the pulley, the hub will "slip" and rotate relative to the pulley instantaneously, i.e., as soon as the alternator armature begins to overrun the pulley. (In order to "smooth out" the performance that will be obtained with such a configuration, it is envisioned that a one-way roller clutch can be connected in series with a torsion spring in similar fashion to the decoupling assembly described above.) Other one-way clutches that can be used include, by way of non-limiting example, a sprag-type clutch or a dither-type one. As yet other possible arrangements, one or more of the various overrunning-enabling configurations disclosed in U.S. Patent No. 6,083,130 (incorporated by reference above) can be provided with an appropriately configured start mode clutch assembly as described above to enable such an overrunning-enabled alternator/generator to be used to start the engine. Moreover, the hub can be integrally formed with the alternator shaft instead of being formed as a separate component, as illustrated. Also, the alternator hub/pulley assembly does not need to be directly connected to the alternator shaft, as shown, but can be interconnected with it in a non-direct arrangement if desired.

[0064] Referring to Figures 8 and 9, a third embodiment of the overrunning-enabled starter/generator is shown, which includes a decoupler in the form of a torsional spring 302 extending between one end 302a fixedly secured to a first hub 304 and a second end 302b fixedly secured to a second hub 306. The torsional spring 302 transmits torque between the first 304 and second 306 hubs. A one-way clutch spring 308 extends between a first carrier end 308a fixedly secured to a first carrier 309 and a second carrier end 308b fixedly secured to a second carrier 310. Each of the first 309 and second 310 carriers are rotatably supported between respective first 304 and second 306 hubs and the pulley 12.

[0065] A shuttle selector in the form of a shaft 320 is axially slidably supported within the overrunning-enabled starter/generator for movement between a first position (Figure 8), wherein the overrunning-enabled starter/generator functions as a starter, and a second position (Figure 9), wherein the overrunning-enabled starter/generator functions as a generator. In the first position, the shaft 320 is disposed between the first hub 304 and carrier 309. In the first position, the shaft 320 rotatably interlocks the first hub 304 and carrier 309, such the first carrier 309 rotates with the first hub 304. Acceleration of the first carrier 309 relative to the pulley 12 expands the wrap spring 308 into engagement with the clutch surface 42 of the pulley 12. Torque from the alternator shaft is directed through the first hub 304 and carrier 309 and to the pulley 12 via the wrap spring 308, bypassing the torsional spring 302.

[0066] In the second position, the shaft 320 is disposed between the second hub 306 and carrier 310. In the second position, the shaft 320 rotatably interlocks the second hub 306 and carrier 310 instead of the first hub 304 and carrier 309, such that the second carrier 310 rotates with the second hub 306. Acceleration of the pulley 12 relative to the second carrier 310 expands the wrap spring 308 into engagement with the clutch surface 42 of the pulley 12. Torque from the pulley 12 is directed to the second hub 306 and carrier 310 via the wrap spring 308. Torque is transferred between the first 304 and second 306 hubs by the torsional spring 302 and, ultimately, to the alternator shaft. Deceleration of the pulley 12 relative to the second carrier 310 causes the wrap spring 308 to contract radially inwardly with respect to the clutch surface 42, which allows the first hub 304 and alternator shaft to overrun the pulley 12.

[0067] A solenoid (not shown) or other suitable linear actuators are operatively coupled between the shaft 320 and the overrunning-enabled starter/generator for selectively moving the shaft 320 between the first and second positions.

[0068] The foregoing preferred specific embodiments have been shown and described for the purpose of illustrating the functional and structural principles of this invention and are subject to change without departure from such principles. Therefore, this invention includes all modifications encompassed within the scope of the following claims.

What is claimed is:

1. An alternator assembly comprising:

a shaft rotatably mounted within a housing, said alternator assembly being configured such that during a driven mode of operation in which said shaft is externally rotated, said alternator produces an electrical output, and during a driving mode of operation in which electrical power is supplied to said alternator assembly, said alternator produces a rotary output; and

a coupling assembly coupled to said alternator shaft for selectively transferring rotary power to and from said shaft, said coupling assembly comprising:

a hub mounted on said shaft;

a pulley rotatably mounted on said hub;

a first clutch operatively engaging said hub and said pulley, said first clutch enabling said pulley to drive said hub while allowing said hub to rotate relative to said pulley; and

a second clutch assembly operatively engaging said hub and pulley, said second clutch selectively interlocking said hub and pulley enabling said hub to drive said pulley.

2. The alternator assembly of claim 1, wherein said first clutch is a torsion spring.

3. The alternator assembly of claim 1, wherein said first clutch is a wrap spring clutch connected in series with a torsion spring.

4. The alternator assembly of claim 1, wherein said first clutch is a wrap spring clutch.

5. The alternator assembly of claim 1, wherein said first clutch is a one-way clutch.

6. The alternator assembly of claim 5, wherein said one-way clutch is a roller clutch.

7. The alternator assembly of claim 1, wherein said hub is able to overrun said pulley as soon as said pulley slows relative to said hub.

8. The alternator assembly of claim 1, wherein said hub is able to overrun said pulley only after a predetermined, level of relative torque between said hub and said pulley is exceeded.

9. The alternator assembly of claim 1, wherein said second clutch assembly is electromagnetically actuated.

10. The alternator assembly of claim 1, wherein said second clutch assembly comprises a wrap spring clutch which interlocks said pulley to said hub when said second clutch assembly is actuated.

11. The alternator assembly of claim 10, wherein said wrap spring clutch is fixed to said hub and overlies a wrap spring-engaging clutch surface of said pulley.

12. The alternator assembly of claim 11, wherein said wrap spring clutch is configured, based on the direction of rotation of said pulley, such that said wrap spring clutch is self-energizing, whereby the volutes of said wrap spring clutch automatically constrict down into clutching engagement with said wrap spring-engaging clutch surface of said pulley when a portion of a volute of said wrap spring clutch is brought into contact with said wrap spring-engaging clutch surface.

13. The alternator assembly of claim 10, wherein said second clutch assembly further comprises a wrap spring actuator ring which surrounds said wrap spring clutch and which initiates interlocking clutching operation of said wrap spring clutch.

14. The alternator assembly of claim 13, wherein said wrap spring clutch is configured, based on the direction of rotation of said pulley, such that said wrap spring clutch is self-energizing, whereby the volutes of said wrap spring clutch automatically constrict down into clutching engagement with said wrap spring-engaging clutch surface of said pulley when a portion of a volute of said wrap spring clutch is brought into contact with said wrap spring-engaging clutch surface, said wrap spring actuator ring being configured to press said portion of a volute into engagement with said wrap spring-engaging surface when said start mode clutch assembly is actuated.

15. The alternator assembly of claim 14, further comprising a lever driver ring surrounding said wrap spring actuator ring, said lever driver ring causing said wrap spring actuator ring to press said portion of a volute into engagement with said wrap spring-engaging surface when said start mode clutch assembly is actuated.

16. The alternator assembly of claim 15, wherein said wrap spring actuator ring has a flexural finger portion that flexes radially inwardly and that is disposed so as to

press said portion of a volute into engagement with said wrap spring-engaging surface when said start mode clutch assembly is actuated.

17. The alternator assembly of claim 16, wherein said lever driver ring slides axially relative to said wrap spring actuator ring and wherein said flexural finger portion and said lever driver ring having opposing ramped surfaces which cooperate to cause said flexural finger portion to press said portion of a volute into engagement with said wrap spring-engaging surface as said lever driver ring slides axially relative to said wrap spring actuator ring.

18. The alternator assembly of claim 17, further comprising an electromagnet which, when energized, causes said lever driver ring to slide axially relative to said wrap spring actuator ring to actuate said start mode clutch assembly.

19. A coupling assembly, comprising:

a hub;

a pulley rotatably mounted on said hub;

a first clutch operatively engaging said hub and said pulley, said first clutch enabling said pulley to drive said hub while allowing said hub to overrun and rotate relative to said pulley; and

a second clutch assembly operatively engaging said hub and pulley, said second clutch selectively interconnecting said hub and pulley to enable said hub to drive said pulley.

20. The assembly of claim 19, wherein said first clutch comprises a torsion spring.

21. The assembly of claim 20, wherein said first clutch further comprises a wrap spring clutch connected in series with said torsion spring.

22. The assembly of claim 19, wherein said first clutch comprises a wrap spring clutch.

23. The assembly of claim 19, wherein said hub is able to overrun said pulley as soon as said pulley slows relative to said hub.

24. The assembly of claim 19, wherein said hub is able to overrun said pulley only after a predetermined, negative level of relative torque between said hub and said pulley is exceeded.

25. The assembly of claim 19, wherein said first clutch comprises a one-way clutch.

26. The assembly of claim 25, wherein said one-way clutch is a roller clutch.

27. The assembly of claim 25, wherein said first clutch further comprises a wrap spring clutch connected in series with said one-way clutch.

28. The assembly of claim 27, wherein said one-way clutch is a roller clutch.

29. The assembly of claim 19, wherein said second clutch assembly comprises an electromagnetic clutch.

30. The assembly of claim 19, wherein said second clutch assembly comprises a wrap spring clutch which interlocks said pulley to said hub.

31. The assembly of claim 30, wherein said wrap spring clutch is fixed to said hub and overlies a wrap spring-engaging clutch surface of said pulley.

32. The assembly of claim 31, wherein said wrap spring clutch is configured, based on the direction of rotation of said pulley, such that said wrap spring clutch is self-energizing, whereby the volutes of said wrap spring clutch automatically constrict down into clutching engagement with said wrap spring-engaging clutch surface of said pulley when a portion of a volute of said wrap spring clutch is brought into contact with said wrap spring-engaging clutch surface.

33. The assembly of claim 30, wherein said second clutch assembly further comprises a wrap spring actuator ring which surrounds said wrap spring clutch and which initiates interlocking clutching operation of said wrap spring clutch.

34. The assembly of claim 33, wherein said wrap spring clutch is configured, based on the direction of rotation of said pulley, such that said wrap spring clutch is self-energizing, whereby the volutes of said wrap spring clutch automatically constrict down into clutching engagement with said wrap spring-engaging clutch surface of said pulley when a portion of a volute of said wrap spring clutch is brought into contact with said wrap spring-engaging clutch surface, said wrap spring actuator ring being configured to press said portion of a volute into engagement with said wrap spring-engaging surface when said second clutch is actuated.

35. The assembly of claim 34, further comprising a lever driver ring surrounding said wrap spring actuator ring, said lever driver ring causing said wrap spring actuator ring to press said portion of a volute into engagement with said wrap spring-engaging surface when said second clutch is actuated.

36. The assembly of claim 35, wherein said wrap spring actuator ring has a flexural finger portion that flexes radially inwardly and that is disposed so as to press said portion of a volute into engagement with said wrap spring-engaging surface when said second clutch is actuated.

37. The assembly of claim 36, wherein said lever driver ring slides axially relative to said wrap spring actuator ring and wherein said flexural finger portion and said lever driver ring having opposing ramped surfaces which cooperate to cause said flexural finger portion to press said portion of a volute into engagement with said wrap spring-engaging surface as said lever driver ring slides axially relative to said wrap spring actuator ring.

38. The assembly of claim 37, further comprising an electromagnet which, when energized, causes said lever driver ring to slide axially relative to said wrap spring actuator ring to actuate said second clutch.

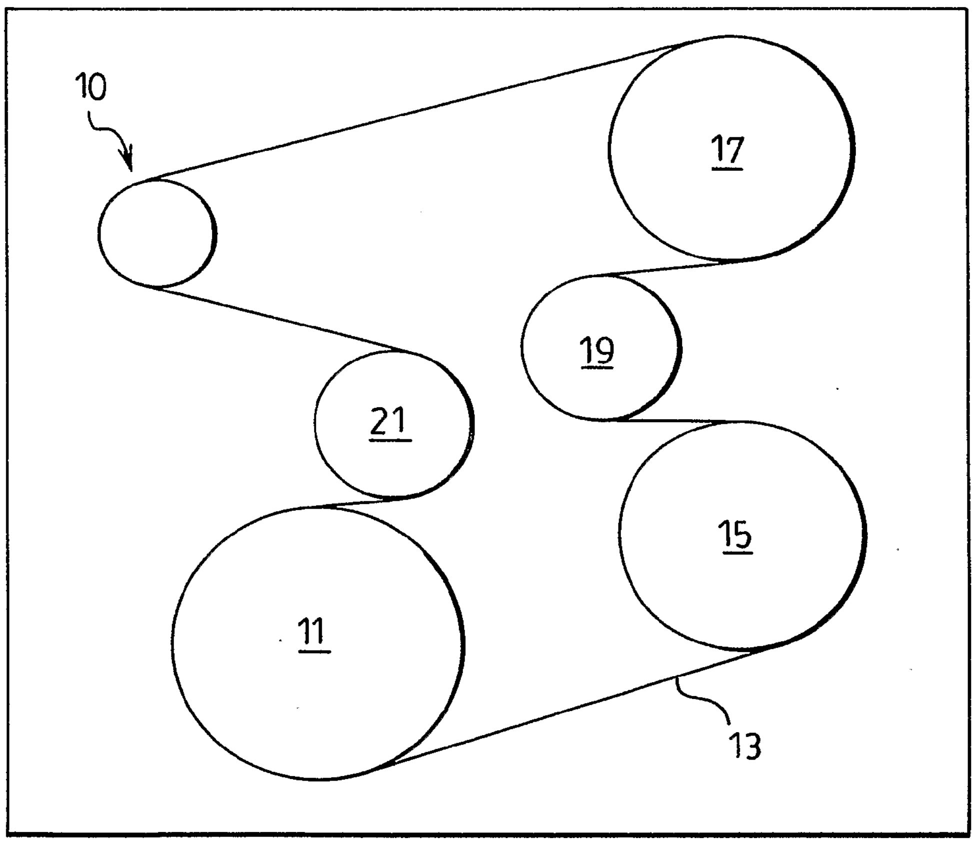
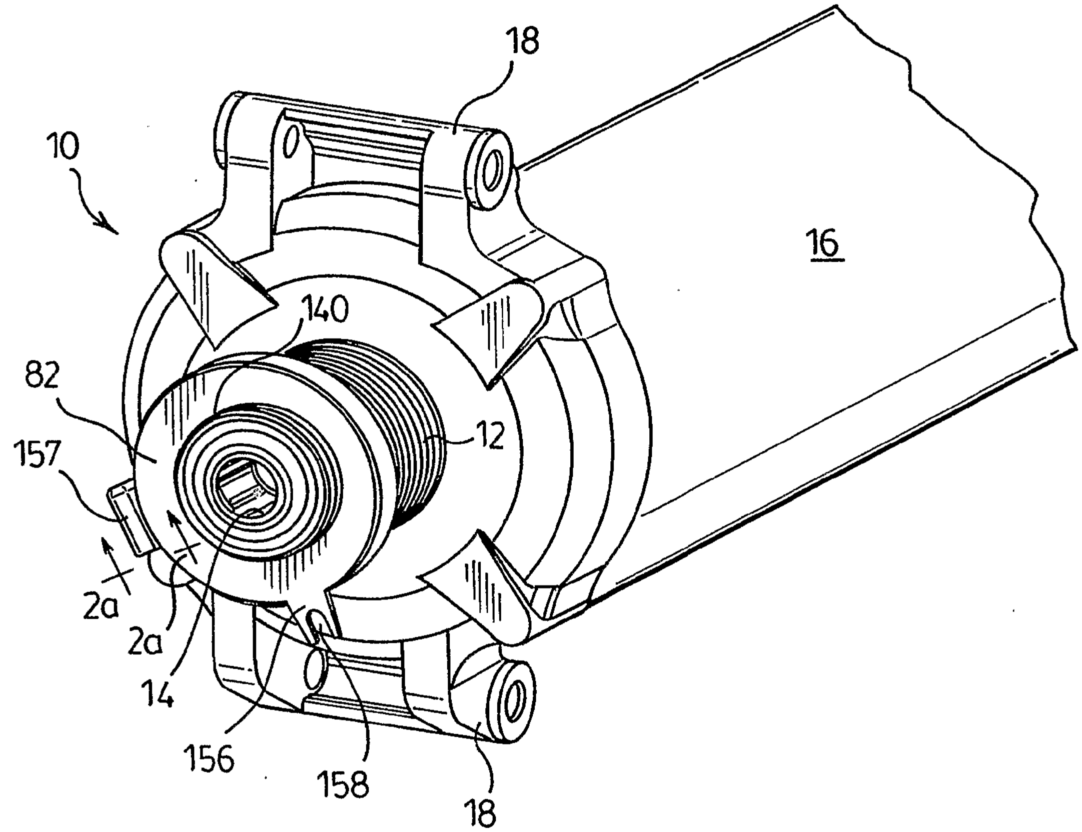


FIG.1.

FIG. 2.



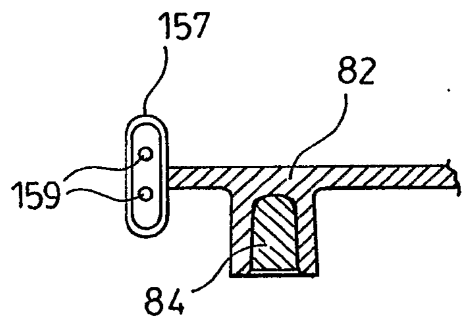


FIG. 2a.

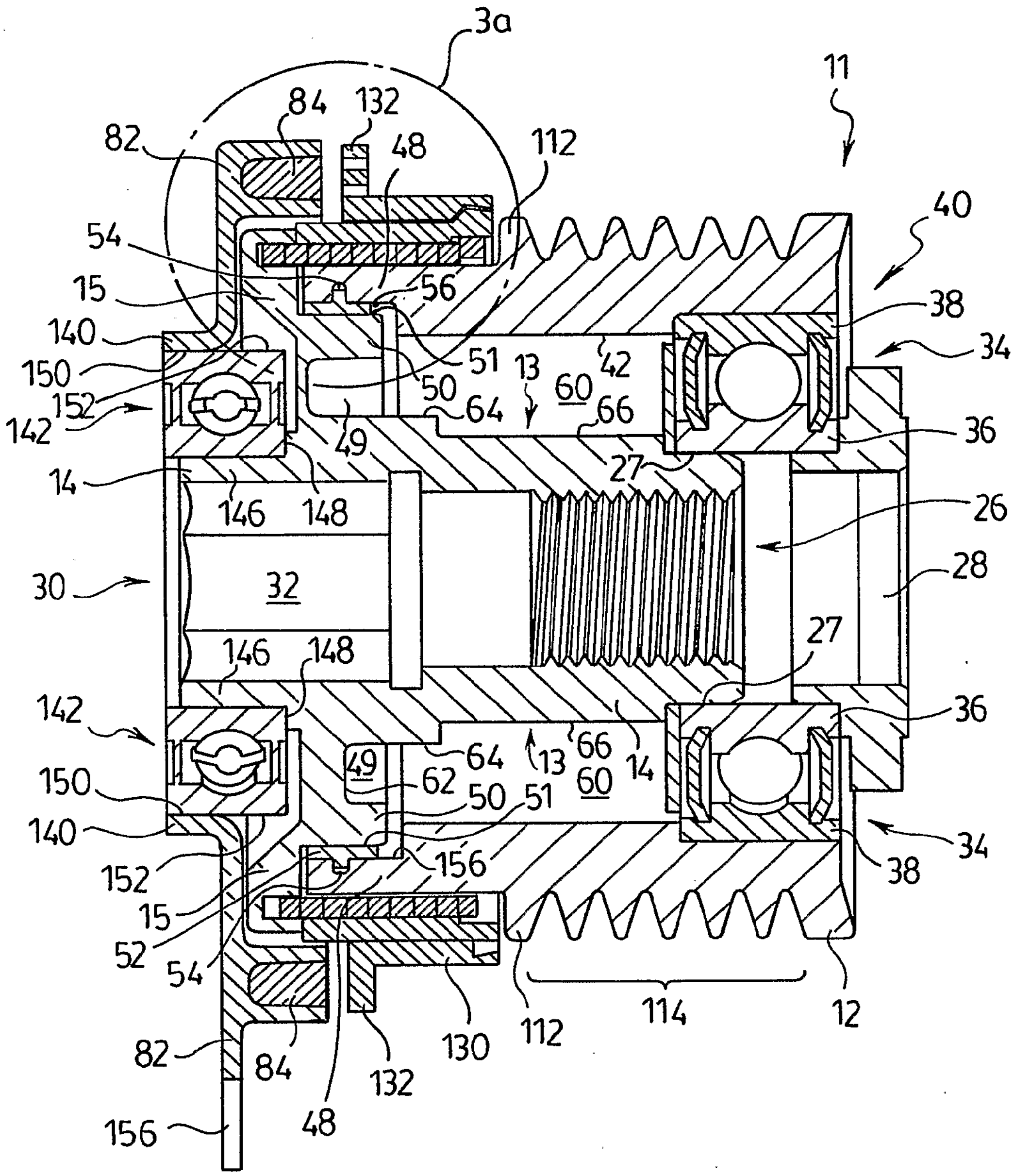

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FIG. 3.

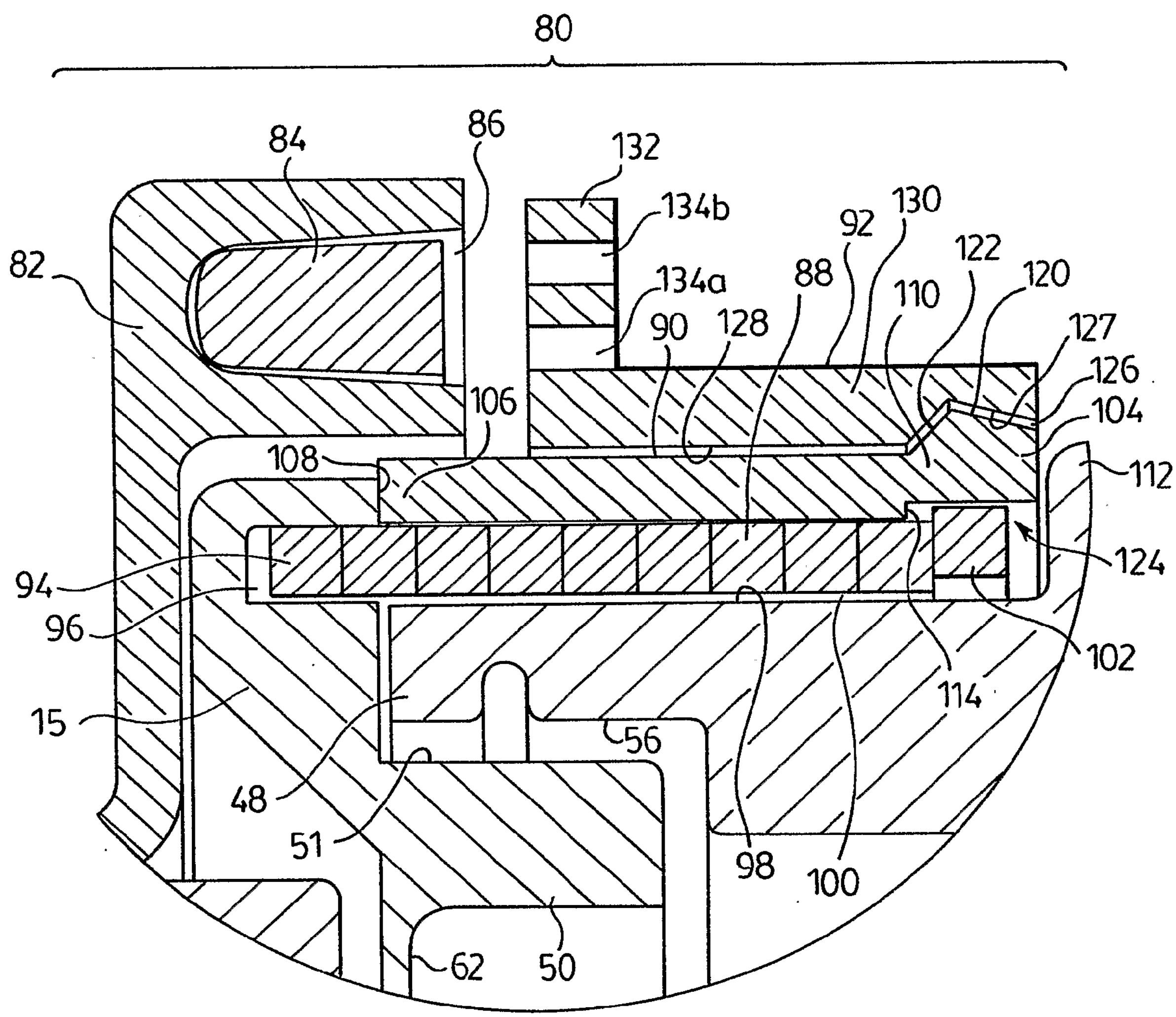
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FIG. 3a.

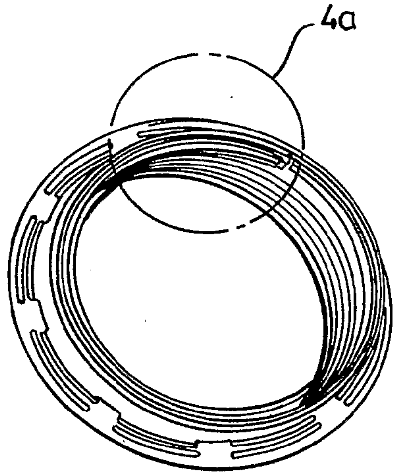

FIG.4.

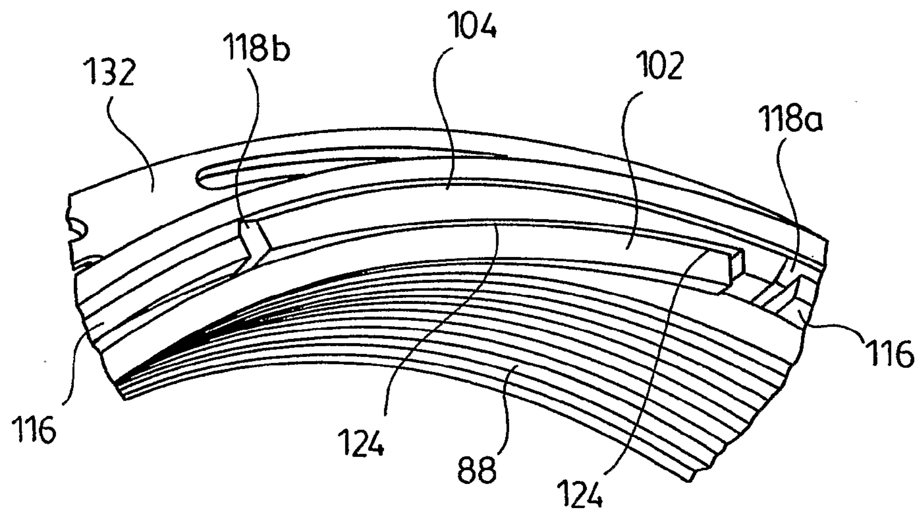

FIG.4a.

FIG.5.

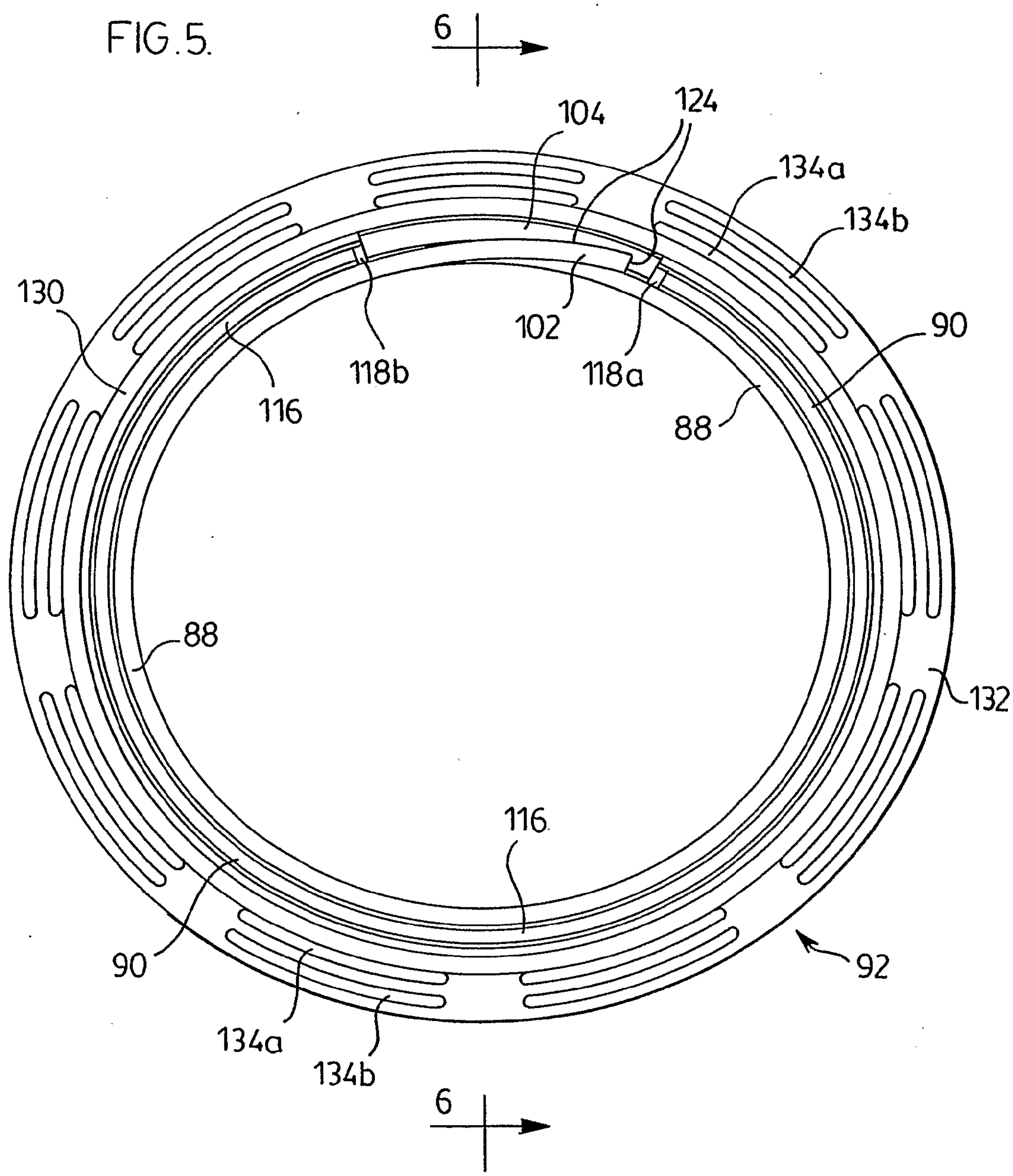
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FIG.6.

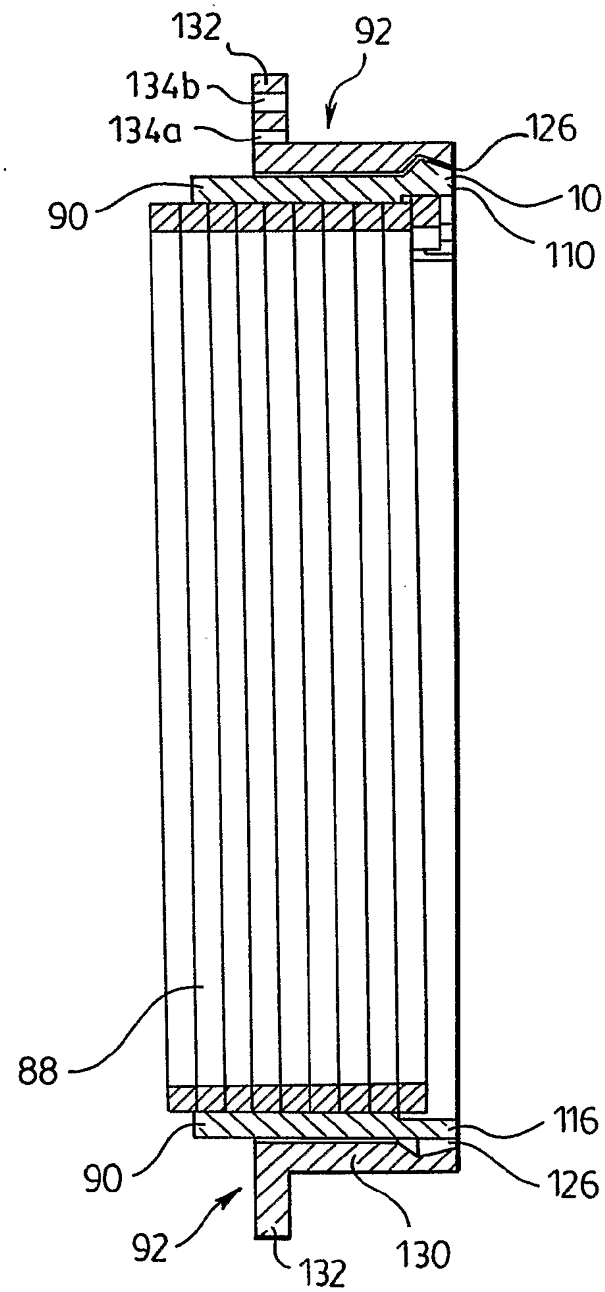

FIG. 7.

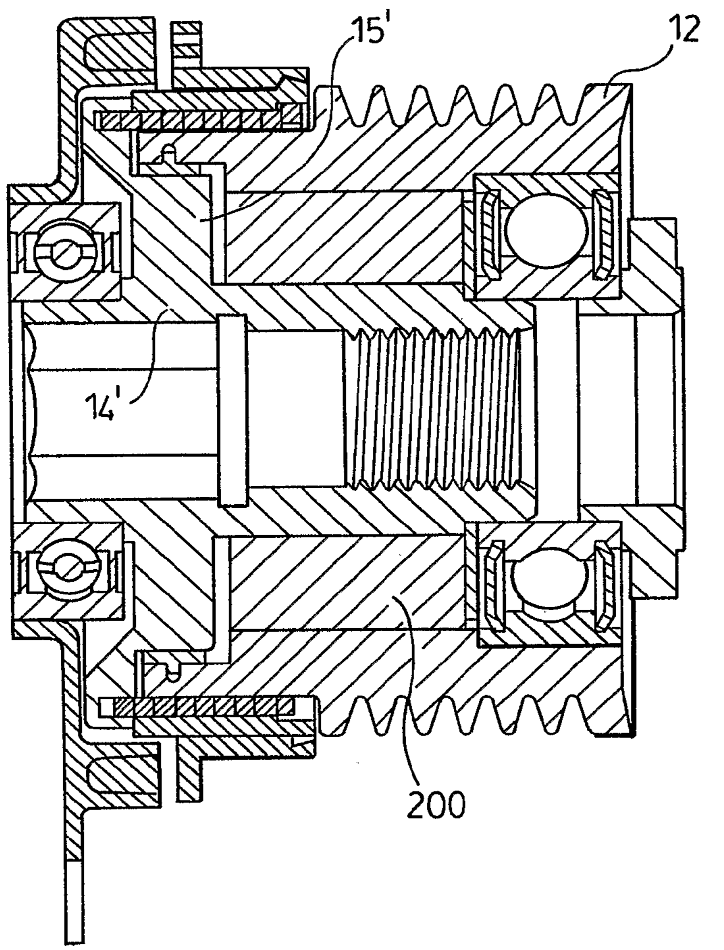

FIG. 8.

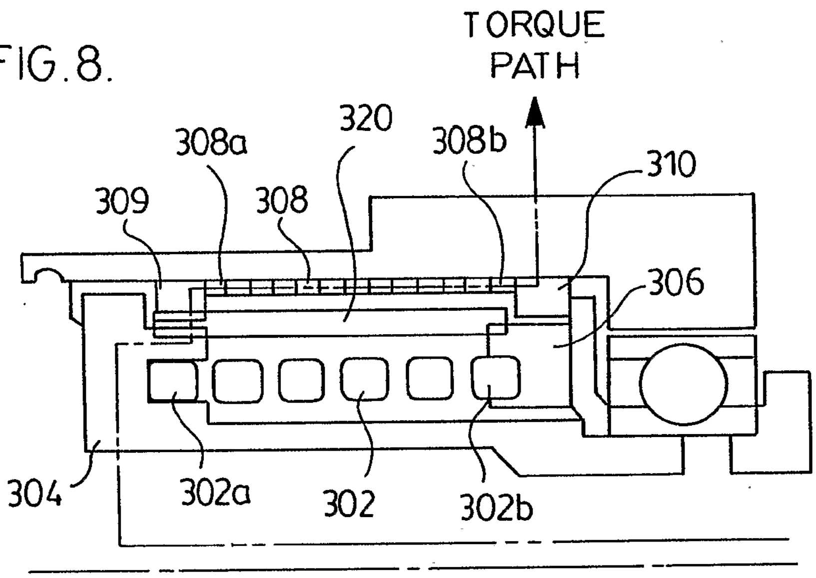
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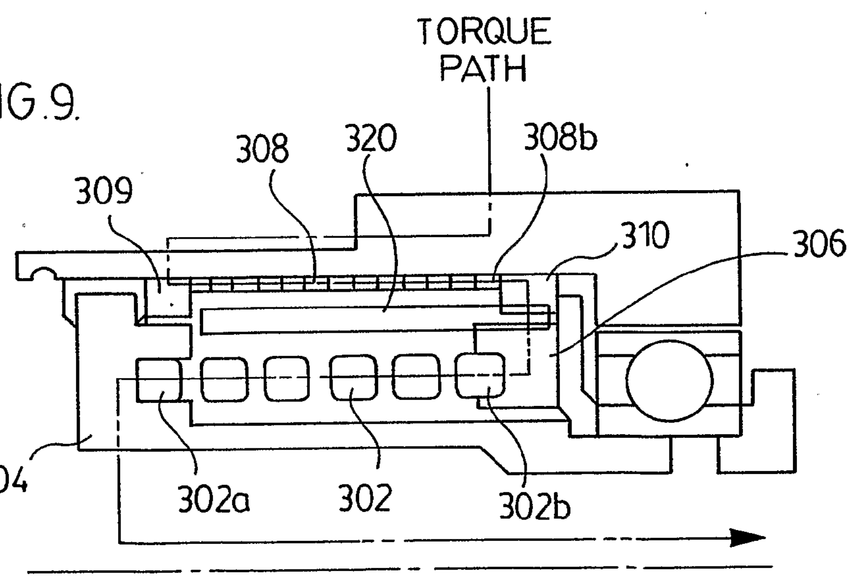
FIG. 9.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INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 03/00852

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16D47/04 F16D27/105 F16D41/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16D F02B F02N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 665 018 A (MIYATA HIROFUMI) 9 September 1997 (1997-09-09) column 7, line 19 -column 8, line 31 figures 1-3 ---	1,5-7, 19,23, 25,26
A	US 2 534 033 A (LA BRIE LUDGER E) 12 December 1950 (1950-12-12) column 2, line 1 -column 4, line 15 column 4, line 72 -column 5, line 4 figures 1,5,8 ---	1,4-6,9, 11,12, 19,22, 25-29, 31,32
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
17 October 2003	24/10/2003

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 03/00852

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